# Numerical modelling of two-phase piezocomposites with interface mechanical anisotropic effects

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Piezocomposite materials and, in particular, two-phase piezoceramic materials with nanosized pores or inclusions are being actively developed in the recent years. The developed in the recent years new nanostructured piezoelectric composite materials have a range of important advantages, such as the possibilities of controllable variation of the functional characteristics within a wide range, the ultra-low mechanical quality factor, etc. Furthermore, the modelling of composite micro- and nanomaterials has the specific features. It is known that some nanomaterials have unconventional physical properties that considerably differ from the characteristics of usual macrosized bodies. Thus, the experimental fact is the increasing of the stiffness with reducing the sizes of nanoobjects. One of the factors that are responsible for this behavior can be surface or interface effects. As research of the recent years shows, for the bodies of submicro- and nanosizes the surface stresses are important and influence the deformation of the bodies. In connection to this, the interesting problem can be an extension of this approach to the nanostructured piezoelectric composite materials.

In present investigation the models of two-phase piezoelectric composite materials developed in the framework of classic continuum approaches of solid mechanics and methods of composite mechanics. These models were used to construct more complicated models of the nanosized piezocomposites that were take into account the surface or interphase mechanical boundary conditions with anisotropic surface properties.

We use an integrated approach to the determination of the effective moduli of nanostructured piezoelecrtric composites with stochastically distributed nanoinclusions. In order to take into account nanoscale level at the borders between two material phases, the Gurtin-Murdoch model of surface stresses are used. ANSYS finite element package was used to simulate representative volumes and to calculate the effective moduli. This approach is based on the theory of effective moduli of composite mechanics, modelling of representative volumes and the finite element method. Here, the contact boundaries between two material phases were covered by the surface membrane elements in order to take the surface stresses into account.

For automated coating of interface boundaries in the cubic representative volume the following algorithm was used. At the beginning, as a result of the formation of the composite structure, the finite element mesh from octanodal cubic elements was created, some of which had the material properties of piezoelectric matrix, and the other part of the elements had the material properties of the inclusions. Further, only the finite elements with material properties of piezoelectric matrix were selected. The resulting elements on the outer boundaries were covered by four nodal target contact elements. Then, the contact elements, which were located on the external surfaces of the full representative volume, were removed, and the remaining contact elements were replaced by the special elastic quasi-shell elements with anisotropic properties inherited by the structure of the main phase. As a result, all the interface facets were coated by elastic quasi-shell shell finite elements.

The next step consisted in solving the static problems for representative volume with the boundary conditions which were conventional for effective moduli method. Further, the averaged stresses and electric fluxes were calculated, both on the volume finite elements and on the surface finite elements for mechanical stresses. Finally, the effective moduli were calculated by using the estimated average characteristics.

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